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HUMAN FACTORS EVALUATION OF THE HIDALGO EQUIVITAL™ EQ-02 PHYSIOLOGICAL STATUS MONITORING SYSTEM

United States Army
Medical Research & Materiel Command

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14. ABSTRACT

Soldiers are particularly vulnerable to thermal strain when they are required to react to chemical, biological, radiological, nuclear, and explosive (CBRNE) threats. One solution to addressing this thermal strain is real-time physiological monitoring to improve situational and health state awareness. One proposed product is the Hidalgo, Ltd. (Cambridge, UK) Equivital™ EQ-02 physiological status monitoring (PSM) system. The usability and acceptability of this system has been tested previously and generally been found to be acceptable by Soldiers for military use. However, no study has examined its use in a CBRNE environment with CBRNE-PPE. This study addressed that need. A total of 28 Soldiers (26 men and 2 women) from the 22nd Chemical Battalion Technical Escort (TE), the 95th Civil Support Team – Weapons of Mass Destruction (CST-WMD) and the 1st CST-WMD volunteered to participate. It was concluded that the Equivital™ EQ-02 system when worn under CBRNE- PPE provided utility and was comfortable to wear.

15. SUBJECT TERMS

Thermal strain; CBRNE; PPE; physiological status monitoring; PSM; human factors; chem-bio

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EXECUTIVE SUMMARY

Soldiers are particularly vulnerable to thermal strain and possible heat illness when they don personal protective equipment (PPE) to react to chemical, biological, radiological, nuclear, and explosive (CBRNE) threats. Heat strain can impair soldier decision making and also result in heat illness casualties. The primary cause of this thermal strain comes from metabolic heat produced from their physical work in heavy equipment, and heat retention due to the encapsulation and impermeability of the PPE they are required to wear. One way to reduce the likelihood of heat illness is to improve situational and health state awareness through real-time physiological monitoring. The Hidalgo, Ltd. (Cambridge, UK) Equivital™ EQ-02 physiological status monitoring (PSM) system is a typical candidate system. The usability and acceptability of this system has been previously evaluated and generally found by soldiers to be acceptable for military use. However, no study has examined this PSM system's use in a CBRNE environment with CBRNE-PPE. This study addressed that need.

Methods: Soldiers (men: 26 and women: 2) from the 22nd Chemical Battalion Technical Escort (TE), the 95th Weapons of Mass Destruction – Civil Support Team (WMD-CST), and the 1st WMD-CST volunteered to participate while completing their regularly scheduled 40 to 75 min training exercises for two or three days while wearing CBRNE-PPE. Upon the conclusion of training, volunteers completed a usability and acceptability questionnaire. The survey contained questions regarding fit, comfort, impact on the body (e.g., causing a rash or skin irritation), impact on military performance, durability, acceptability, utility, and affective feelings when wearing the system (e.g., feeling strange, or being uncomfortable wearing the device given its appearance). Survey questions were open-ended or in the form of Likert-type, e.g., 5- or 7-point rating questions.

Results: The overall fit of the system received a score of 5.5 $\pm$ 1.7 (5 = "Like Slightly" and 6 = "Like Moderately") on a 7-point scale. Average system rating was slightly comfortable, (5.1 $\pm$ 1.5). There was between a slight negative (score = 4) and no negative impact (score = 5) regarding its affect on various military performance tasks or its impact on the body. All affective feelings of the system were positive. When asked if the system was acceptable to wear for eight hours or longer, 89% of soldiers said it would be acceptable. Additionally, 89% of soldiers said they would wear the system if it helped improve the medical care they would receive, and 96% of soldiers said they would recommend this system for use in training or actual missions.

Conclusions: Soldiers reported that the Equivital™ EQ-02 system was useful and could be worn comfortably under CBRNE- PPE. Durability was not an issue, but these exercises were brief in duration and relatively new PSM systems were used. Future research should address long term use, e.g., many washes up to the manufactured suggested 25 washes to ensure that durability remains a non-issue. Finally, a study addressing whether the process of physiologically monitoring individuals in a CBRNE environment with a PSM system actually improves situational awareness and reduces the risk of heat illnesses is still needed.

INTRODUCTION

Chemical weapons have been used in previous conflicts by various countries and terrorists, and continue to be a threat to the United States (5). The use of chemical, biological, radiological, and nuclear (CBRN) agents continues by countries and individual terrorists despite international agreements banning their use. Soldiers need to be protected from these agents. Specialized personal protective equipment (PPE) is used to help ensure soldiers' safety when operating in chemical, biological, radiological, nuclear, and explosive (CBRNE) environments. Ensuring the safety of soldiers and others working in CBRN-PPE is as paramount today as during the first two World Wars when CBRN agents were infamously used.

The threats to our active duty military and international weapons inspectors have risen with the recent chemical attacks in Syria. These attacks have led to the United Nations employing chemical weapons' inspectors to assess the evidence of chemical weapons use by the Syrian government (12). During the preparation of this report, Syria agreed to a Russian proposal to dispose of its chemical weapons (6). Those workers disposing of these weapons will likely be required to wear CBRNE-PPE. Other events such as the Boston Marathon bombing, with the 1st Weapons of Mass Destruction – Civil Support Team (WMD-CST) responding (11), and ricin letters that were intercepted en route to a member of Congress and the President (2), also require the use of CBRNE-PPE by law enforcement personnel. Routinely, the WMD-CST and law enforcement officers investigate hazardous material drug lab sites where wearing CBRNE-PPE is necessary.

For over twenty years, real-time physiological monitoring has been proposed as a way to manage thermal strain (1). A concept system was proposed as part of the Warfighter Physiological Status Monitoring (WPSM) program (8) that led to the early development of the current Food and Drug Administration (FDA) 510(k) certified Hidalgo Equivital™ (Hidalgo Ltd., Cambridge, UK) physiological status monitoring (PSM) system. This system has gone through a number of different developmental iterations (13, 14) to ensure its operability in the environments soldiers operate in. It has also been developed to ensure it is as comfortable, acceptable, and minimizes the impact on the wearer's activities as possible.

Soldiers are particularly vulnerable to thermal strain when they are required to wear PPE when responding to CBRNE threats. While work load, in terms of energy expended and metabolic heat production, may be less than other more physically active soldiers (16, 17), the use of CBRNE-PPE can increase core temperatures by impeding the loss of body heat via evaporation, convection and conduction cooling mechanisms (9). In 2007, real-time physiological monitoring with commercial-off-the-shelf (COTS) equipment was demonstrated with WMD – CST personnel encapsulated in CBRNE-PPE (4). While there were limitations to the capability of the COTS system, that study demonstrated the feasibility of using PSM technology to monitor heat strain. A usability evaluation of the Hidalgo Equivital™ EQ-01 PSM system (Equivital™ EQ-01, Hidalgo, Ltd., Cambridge, UK) was completed during that evaluation (13). Previous usability

evaluations with various groups of warfighters (13, 14) including results from that WMD-CST study identified three main issues with the EQ-01 PSM system related to the sensor electronics module (SEM) mounted in the center of the chest: 1) discomfort when individuals wore body armor, 2) interference with mission critical tasks such as shooting in the prone position and low crawling, and 3) interference with a person's ability to sleep. As a result of these issues, Hidalgo Ltd., with funding from the U.S. Army developed a smaller SEM and moved the location of the SEM from the center of the chest to the side of the chest (thorax) just below the left axilla. A study was subsequently conducted with infantry and cavalry soldiers to ensure the new design and location of the new smaller SEM was superior to the old design. That evaluation showed the new design of the EQ-02 resulted in a better fit, more comfort, less negative impact on the body or on job performance, and greater acceptability than the older EQ-01 design (15).

This report documents, the EQ-02 system's fit, comfort, impact on performance, impact on the body, affective feelings of wearing the system, durability, and acceptability of the system when worn under CBRNE-PPE. These results document the system's utility and acceptability by the soldiers who used the system while wearing CBRNE-PPE and performing CBRNE training.

METHODS

VOLUNTEERS

Twenty eight soldiers participating in scheduled CBRNE training served as test volunteers. Volunteers included soldiers from the 22nd Chemical Battalion Technical Escort (TE) (*n* = 13; 12 men and 1 woman), Aberdeen Proving Grounds, Edgewood, MD, the 95th WMD-CST from Hayward, CA (*n* = 7; all men), and the 1st WMD-CST from Wellesley, MA (*n* = 8; 7 men and 1 woman). The study was approved by USARIEM's Scientific Review and Human Use Review Committees (SRC and HURC). Volunteers were briefed on the purpose, risks, and benefits of the study and each gave their written informed consent prior to study participation. Soldiers averaged 29.6 $\pm$ 6.1 (mean $\pm$ standard deviation) years of age and had 7.9 $\pm$ 5.5 years of military service. All had previous CBRNE training, had worn CBRNE-PPE previously, and had been training with their units a minimum of two years. These volunteers weighed 83 $\pm$ 13 kg and were 177 $\pm$ 72 cm tall. All volunteers participated in regular physical training.

TRAINING EXERCISES

22nd Chemical Battalion Technical Escort (TE):

The EOD personnel conducted initial entry after walking approximately 10 meters in EOD-PPE. Personnel searched and disarmed simulated explosive devices. The TE personnel then entered and searched the area for chemical weapons. They secured

the weapons and/or samples of chemical substances. The TE personnel wore the Joint Service Lightweight Integrated Suit Technology (JSLIST) with a chemical protective M52 Mask and Interceptor Body Armor. The exercise concluded with downrange personnel returning to the staging area and undergoing the Emergency Personnel Decontamination Station (EPDS) procedures. Training was similar on all three days, with each session lasting between 50 and 75 min.

95th Weapons of Mass Destruction - Civil Support Team:

Approach March (Day 1): Soldiers in Level A CBRNE-PPE with a self contained breathing apparatus (SCBA) walked self-paced for approximately 40 minutes covering just less than 2 kilometers. This simulated an approach to a CBRNE "hot zone" site.

Sampling (Day 2): Soldiers walked approximately 400 meters into a designated contaminated area which simulated an illicit drug laboratory. Soldiers were required to search and secure the room. They also secured a sample of the simulated chemical materials present, properly packaged and documented the sample, then returned the sample to the decontamination line for processing prior to transferring the sample to the CST mobile Analytical Laboratory System (ALS) for analysis. All volunteers were encapsulated in Level A CBRNE-PPE for approximately 40 min while doing their assigned jobs.

Search and Rescue (Day 3): Soldiers completed a search and rescue operation in a four-story fire tower. They searched the area, cleared rooms, and rescued a downed person (~85 kg manikin). All volunteers were encapsulated in Level A CBRNE-PPE for approximately 40 min while doing their assigned jobs.

1st Weapons of Mass Destruction - Civil Support Team:

All volunteers wore Level A CBRNE-PPE during two days of training exercises. Six volunteers used SCBA while two volunteers used Powered, Air-Purifying Respirator (PAPR) systems. The training exercises were less than 60 min in duration.

Two soldiers constructed a subway track berm. Activities included carrying a heavy container (~23 kg) and assembling materials according to a standard operating procedure (SOP) to create this berm. This task was in support of the Integrated Detection and Decontamination Demonstration (IDDD) program. The constructed berm would collect runoff of decontaminated liquids used to clean the contaminated subway tracks. The WMD-CST personnel wore CBRNE-PPE while constructing this berm.

Six other soldiers participated in a search and rescue operation in an abandoned building simulating a chemical laboratory. They were required to secure and move a flexible stretcher (i.e., a sked) with a simulated human casualty (~85 kg manikin), inventory chemical glass-ware, and reassemble the chemical glassware equipment in

the way they found it (cognitive and fine motor tasks). Throughout this exercise, they moved up and down stairwells of a three-story building.

MATERIALS

Physiological Monitoring System

The Equivital™ EQ-02 system consists of a chest belt/harness and the SEM (Figure 1). It is an FDA 510(k) certified device. The system records heart rate, respiration rate, and skin temperature. Tri-axial accelerometers located within the SEM are used to determine body orientation (i.e., upright, supine, or prone positions) and activity patterns. The SEM also serves as the receiver for core temperature data transmitted by a telemetric core thermometer pill (Mini Mitter, Bend, OR). The SEM weighs about 41.3 g and is 7.7 cm x 5.3 cm x 1.1 cm. It is attached to the chest strap with a connector and inserted in a pouch under the left arm.

Figure 1. Hidalgo Equivital™ EQ-02 System.

Harness/Belt

Sensor Electronics Module (SEM)

Survey

The survey (Appendix A) has been used in a previous evaluation of the EQ-02 system with infantry and cavalry soldiers (15). The survey contained questions about fit, comfort, impact on the body (e.g., causing a rash or skin irritation), impact on military performance, durability, acceptability, utility, and affective feelings (e.g., feeling strange, or being uncomfortable wearing the device given its appearance) regarding wearing the PSM system. Survey questions were in the form of open-ended and Likert-type questions. For example, soldiers were asked to rate the comfort of the system on a 1 to 7 scale, from very uncomfortable to very comfortable. An example of an open-ended question was “Please explain why you would not wear the system.” This survey also

included 21-point questions previously developed (10) to assess psychological affective feelings of wearing body sensors. The scale ranges from -10 (negative affective feelings) to 0 (neutral feelings) to +10 (positive affective feelings). Volunteers were instructed to circle the number that most closely responded to their feelings.

DATA ANALYSIS

Means and standard deviations (SD) were calculated from the subjective rating scales. Frequencies of responses with proportions of various responses were calculated. Chi-square and one-way analyses of variance were run to determine significant differences between test groups. Significance level was set a $p < 0.05$. A Bonferonni adjustment was made to the results given the high number of analyses performed. Without an adjustment only two variables showed a significant difference, but these differences were not evident when the Bonferroni adjustment was applied. Since no significant differences existed among the three test groups the data presented in the results combine the three test groups into one overall sample.

RESULTS

FIT

All participants reported that the EQ-02 system fit them comfortably. When participants were asked to rate the fit of the system, the overall fit, and the fit in specific anatomical areas, all ratings were better than “Like Slightly” (see Table 1).

Table 1. Fit ratings of the EQ-02 system on various body area regions.

Body Area of Fit	(Mean $\pm$ SD; n = 28)
Overall	5.5 $\pm$ 1.7
Chest	5.4 $\pm$ 1.7
Shoulders	5.5 $\pm$ 1.5
Neck	5.6 $\pm$ 1.3
Back	5.7 $\pm$ 1.3

1 = Dislike Very Much, 2 = Dislike Moderately, 3 = Dislike Slightly, 4 = Neither Like nor Dislike 5 = Like Slightly, 6 = Like Moderately, 7 = Like Very Much

Table 2 compares the reported tightness-looseness of fit of the EQ-02 system. A rating of 4 is optimal, while values less than 4 represent feelings that the system was too tight on the body, and values greater than 4 indicate the system being too loose on the body. Responses were mostly between a score of 3 and 4; slightly too tight.

Table 2. Tightness-looseness ratings of the EQ-02 system.

Body Area of Tightness/Looseness of System	(Mean ± SD; *n* = 28)
Overall	3.4 ± 0.8
Chest	3.3 ± 0.9
Back	3.6 ± 0.7
Shoulders	3.5 ± 0.8
Neck	3.6 ± 0.7

1 = Very Tight, 2 = Moderately Tight, 3 = Slightly Tight, 4 = Neither Tight nor Loose, 5 = Slightly Loose, 6 = Moderately Loose, 7 = Very Loose

COMFORT

When soldiers in CBRNE-PPE were asked if the EQ-02 system was comfortable, 82% responded that it was. Those that reported it was uncomfortable were then asked if there were specific activities when the system was uncomfortable to wear. The following activities were reported to elicit discomfort:

- Bending down with Interceptor Body Armor
- Sitting down
- Bending over during sampling tasks
- Rescue operations when squatting or bending over to attend to a casualty
- Putting on protective clothing

The overall comfort and the comfort of the all the individual components of the system were rated better than slightly comfortable (Table 3).

Table 3. Comfort ratings of the EQ-02 system components.

Comfort of System Component	(Mean ± SD; *n* = 28)
Overall System	5.1 ± 1.5
Electrodes	5.4 ± 1.3
Area Under Sensor Electrode Module	5.3 ± 1.3
Belt	5.2 ± 1.5
Adjustment Hooks	5.2 ± 1.5
Shoulder Strap	5.2 ± 1.4

1 = Very Uncomfortable, 2 = Moderately Uncomfortable, 3 = Slightly Uncomfortable, 4 = Neither Comfortable nor Uncomfortable, 5 = Slightly Comfortable, 6 = Moderately Comfortable, 7 = Very Comfortable

IMPACT OF THE SYSTEMS ON MILITARY PERFORMANCE

Soldiers were asked to rate the impact of wearing the EQ-02 system on general military tasks. A 5-point scale was used to assess the impact, with "1" being "Extreme Negative Impact" to "5" being "No Negative Impact." Specific questions were asked regarding impact with and without body armor, while wearing CBRNE-PPE. The 22nd Chemical Battalion TE was the only group that performed activities in body armor. There were eleven soldiers that reported wearing body armor for a total of 5.0 ± 3.2 hours over three days of CBRNE training. Table 4 is a summary of the ratings under the different equipment configurations.

Table 4. Impact on military performance of the EQ-02 system for various equipment configurations.

Impact on Military Performance	Mean ± SD
No CBRNE PPE/No Body Armor (*n* = 25)	
Overall	4.3 ± 1.6
Ease of Body Movement	4.4 ± 1.7
Running	3.2 ± 2.4
Bending	4.2 ± 1.8
CBRNE PPE/No Body Armor (*n*= 27)	
Overall	5.0 ± 0.2
Ease of Body Movement	5.0 ± 0.2
Running	5.0 ± 0.2
Bending	4.9 ± 0.4
CBRNE PPE/ With Body Armor (*n* = 11)	
Overall	4.9 ± 0.3
Ease of Body Movement	5.0 ± 0.0
Running	5.0 ± 0.0
Bending	4.7 ± 0.5

1 = Extreme Negative Impact, 2 = Very Negative Impact,3 = Moderate Negative Impact, 4 = Slight Negative Impact, 5 = No Negative Impact

IMPACT OF THE SYSTEMS ON THE BODY

Soldiers were asked to rate whether the systems caused skin irritation or other physical discomfort. When specifically asked about the impact to the body, the same 5-point scale was used, as was used for determining the impact of the systems on military performance (Table 5). Four (14%) soldiers cited the system caused skin irritation or discomfort. When asked to describe what caused the skin irritation or discomfort, two comments focused on overall discomfort of the system, while the other two comments

focused on the shoulder strap causing skin irritation or chafing. These were the following responses:

- "Not comfortable"
- "Slight irritation to the underarm area where the shoulder strap rests"
- "On the third day I had skin irritation which was basically a chaffing on the front shoulder where the shoulder strap was"
- "The overall system is uncomfortable to wear. There is added discomfort when wearing protective equipment because we already have so much on our body

Table 5. Impact of the EQ-02 system and its various components on the body.

Impact on the Body	(Mean ± SD; *n* = 28)
Overall System	4.8 ± 0.5
Electrodes	4.9 ± 0.4
Area Under Sensor Electrode Module	4.9 ± 0.4
Belt	4.9 ± 0.4
Adjustment Hooks	4.8 ± 0.5
Shoulder Strap	4.9 ± 0.4

1= Extreme Negative Impact, 2 = Very Negative Impact, 3 = Moderate Negative Impact, 4 = Slight Negative Impact, 5 = No Negative Impact

AFFECTIVE FEELINGS WHEN WEARING THE SYSTEM

Regarding affective feelings, the EQ-02 system was always rated above the neutral point (0 score) towards the positive adjective on each affective state scale (Table 6).

Table 6. Affective feelings of wearing the EQ-02 system.

Affective State	(Mean ± SD; *n* = 28)
Worried/Confident	6.2 ± 4.7
Feel Device/Wear and Forget	3.5 ± 6.3
Causes Harm/Is Beneficial	5.3 ± 4.8
Feels Strange/Feels the Same	5.4 ± 5.1
Restricts Movement/Freedom to Move	5.6 ± 4.9
Secure/Insecure	6.1 ± 4.9

-10 to 0 Negative Affective State, 0 to 10 Positive Affective State

DURABILITY OF THE SYSTEM

Throughout the study, volunteers and research staff recorded if the system broke or failed. There was only one volunteer (out of 28) whose system failed to record data. This volunteer was refitted a number of times, but data was still not recorded accurately or reliably.

ACCEPTABILITY

Participants were asked "would the system be acceptable to wear for eight hours or longer in a CBRNE environment." The majority, 25 of 28 soldiers (~89%), believed the system would be acceptable for extended wear. The three that did not believe it would be acceptable, provided the following responses for why it would not be acceptable:

- "After a few hours with PPE and body armor on nothing feels good"
- "Shoulder strap on belt grew uncomfortable"
- "It will cause a rash, something that close to the body for that long needs to be better"

When soldiers were asked if they would wear the system during a CBRNE event if it would allow them to receive better medical care to improve their health or save their life, the majority, 25 out of 28 soldiers (~89%), said they would. For the three that said they would not wear the system, the following responses were provided:

- "Because the radio link has the possibility of being a hazard with bomb disposal"
- "Would only wear system if made to"
- "It is good for training so that we can stress our body more and not worry about heat injury. On a real mission we have a lot of information to process, this would add to info overload for the group leader"

When these soldiers were asked if they would recommend this system for use in CBRNE training or during actual missions, 27 of the 28 soldiers (~96%), said they would recommend this system. The one person who said he would not recommend the system, said that he was not medically qualified to make any kind of recommendation regarding this or similar systems to others. The following open-ended comments were added when asked for any other comments:

- "I would recommend this if there were situations where the radio signal was not a hazard to the person"

- "Good, but only for training. Good concept, however we don't have the ability to stop a mission due to someone overheating. It is good to train to know and understand our limits and how we can try to extend them"

- "Great" (*n* = 2)

- "Sweet"

DISCUSSION

The results of this study indicate that the EQ-02 system met the needs of soldiers wearing CBRNE-PPE while doing a variety of mission-relevant activities. These results are similar and corroborate the findings of soldiers participating in ground infantry training with and without body armor (14). While extended wear of the PSM system was not examined in the present study, there were no early indications that wearing the system for extended periods of time would be problematic. Furthermore, most CBRNE training and mission events are 45 to 120 minutes in duration. These duration limits result from the air available in SCBA tanks.

The use of PSM systems that are acceptable to wear and provide utility in monitoring health status, especially to prevent heat illnesses, is especially relevant in light of the CBRNE events/situations both in the United States and abroad. The recent development of an algorithm to accurately estimate core body temperature from heart rate allows the use of the PSM system without the need to ingest costly core thermometer pills (3). An easy-to-use 1 to 10 heat strain index (HSI), previously reported from this study, showed the varied individual thermal strain responses while working and encapsulated in CBRNE-PPE (18). This variability in thermal strain while working in CBRNE-PPE among individuals illustrates the utility of real time physiological monitoring.

Two statements were made in the open-ended comments on the survey about the concern of the radios that are used as part of the PSM system. These direct quotations written on the survey on why the system might not be acceptable were: 1) "[I would not wear the system] because the radio link has the possibility of being a hazard with bomb disposal" and 2) "I would recommend this [system] if there were situations where the radio signal was not a hazard to the person." It cannot be verified exactly what these statements refer to. However, given they were made by EOD soldiers it is suspected they refer to detectability of soldier location and/or the hazard of triggering a bomb. For on-body communications, the Equivital™ EQ-02 systems use standard commercial Bluetooth® radios, exactly the same as utilized in smartphone headsets and earpieces; wireless keyboards; and numerous other consumer devices. Off-body communications are handled via the terrestrial trunked radios (TETRAs) (Sepura; Cambridge, UK). These radios are commonly used by European public safety organizations, and are equivalent to the radios the teams routinely carry for voice

communications. While there is no known health risks associated with wearing or using these radio devices, the tactical operational concerns voiced by these soldiers are valid. That is, the radio links may be a hazard with regard to detecting a soldier's location and/or triggering a bomb by listening to various Bluetooth® transmissions or radio signals from the TETRA radios. Because of these possibilities, efforts are underway to develop next generation PSM systems that do not depend upon commercial Bluetooth® radios. These next generation systems are intended to be fully useable in a tactical environment. They will feature radio links with very low probability of detection properties. If a signal cannot be detected, it cannot be used to identify soldier location or trigger a bomb. An example of this type of link technology is Ultra Wide Band (UWB). These UWB radios bury their signals in the ambient radio frequency noise and thus are impossible to detect unless the radios have been synchronized beforehand. In order to mitigate risks posed by the off-body communications links, radio silence would need to be observed; preferably by turning the radios off. This would be true of any long-haul radio whether it was used for a team's normal voice communications, only for data, or for combined voice and data communications.

The durability of the system was not an issue during these exercises. However, an important caveat is that these systems were relatively new. An assessment of the durability should take place after 20 washes of the system. The manufacturer's user's guide suggests the harness/belt should be good for 25 washes (7).

CONCLUSIONS

This study documented that the Equivital™ EQ-02 system when worn under CBRNE-PPE was perceived to be useful and comfortable. In addition, the evaluated system did not impact the mission or the body significantly, and elicited positive affective feelings.

Future research should evaluate the long term use of these systems to document system durability. Finally, and most importantly, a study addressing whether the process of medically monitoring individuals in a CBRNE environment with a PSM system actually improves situational awareness and reduces the risk of heat illnesses is still needed.

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APPENDIX A

User Survey

*Identification Number:*_____

This monitoring device is a medical system that has been made to send health data to a medic or your buddy to help prevent injuries in training and also to send information in a time of emergency. The system measures breathing rate, heart rate, skin temperature, body position and activity. The system will allow injuries to be prevented and treatment and aid sent to wounded warfighters more quickly.

We would like to know your opinions about the comfort and fit of this device during your training exercise. By answering the questions below you will help us create a better product.

1. Did the system fit you properly?

○ Yes

○ No ⟶ If No: 1a. Please explain why it did not fit you properly.

---

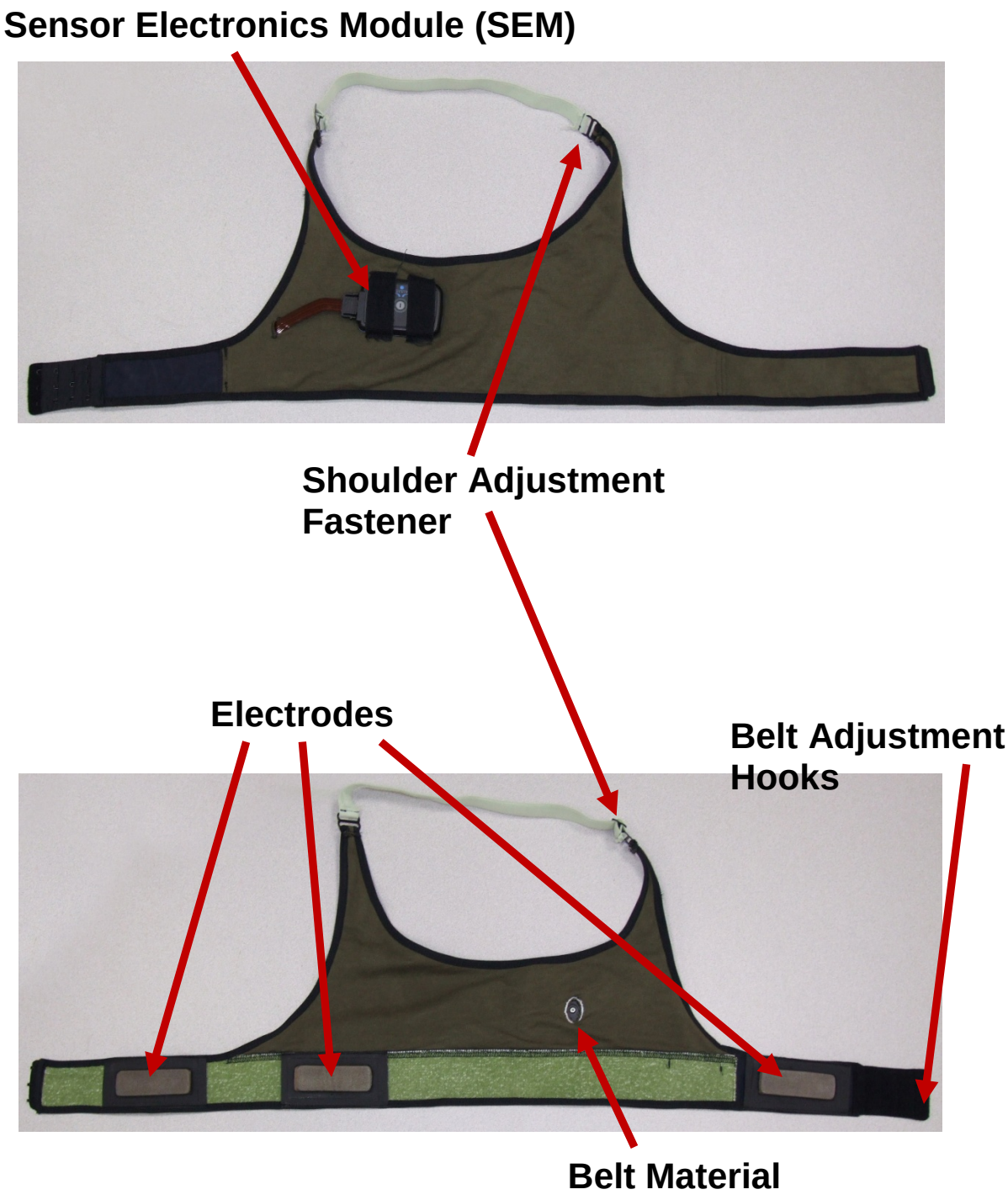
2. Using the following scale please rate how much you like or dislike the fit of the monitoring system for the following areas:

	Dislike Very Much 1	Dislike Moderately 2	Dislike Slightly 3	Neither Like nor Dislike 4	Like Slightly 5	Like Moderately 6	Like Very Much 7
a. Overall	○	○	○	○	○	○	○
b. Chest	○	○	○	○	○	○	○
c. Shoulders	○	○	○	○	○	○	○
d. Neck	○	○	○	○	○	○	○
e. Back	○	○	○	○	○	○	○

3. Using the following scale please rate, how tight or loose, the fit of the monitoring system was for the following areas:

	Very Tight 1	Moderately Tight 2	Slightly Tight 3	Neither Tight nor Loose 4	Slightly Loose 5	Moderately Loose 6	Very Loose 7
a. Overall	○	○	○	○	○	○	○
b. Chest	○	○	○	○	○	○	○
c. Shoulders	○	○	○	○	○	○	○
d. Neck	○	○	○	○	○	○	○
e. Back	○	○	○	○	○	○	○

For Questions Below Please Use This Photo



Please rate how comfortable or uncomfortable you found the system during your training exercise. Rate the system overall and for the individual parts of the belt listed for the question: (*Match the question letter to the belt area on the on the diagram above*).

4. COMFORT	Very Uncomfortable 1	Moderately Uncomfortable 2	Slightly Uncomfortable 3	Neither Comfortable nor Uncomfortable 4	Slightly Comfortable 5	Moderately Comfortable 6	Very Comfortable 7
a. Overall	○	○	○	○	○	○	○
b. Electrodes	○	○	○	○	○	○	○
c. Area Under Electronics Module	○	○	○	○	○	○	○
d. Belt Material	○	○	○	○	○	○	○
e. Belt Adjustment Hooks	○	○	○	○	○	○	○
f. Shoulder Adjustment Fastener	○	○	○	○	○	○	○

5. While wearing the system during your training approximately how long did you spend in the following activities:

5a. Sleeping or trying to sleep? _____ hours
5b. Wearing body armor? _____ hours
5c. In Personal Protective Equipment? _____ hours

6. Was there a particular activity or activities during your training when you found the system to be more uncomfortable to wear?

○ No

○ Yes ⟶ If Yes: 6a. What was the activity(s)?

_____

_____

Questions 7 through 10. Please rate whether the system had an impact on your overall performance and for the other activities listed:

7. No Body Armor or No Personal Protective Equipment	Not Applicable	Extreme Negative Impact 1	Very Negative Impact 2	Moderate Negative Impact 3	Slight Negative Impact 4	No Negative Impact 5
a. Overall impact on performance	[redacted]	○	○	○	○	○
b. Ease of motion	[redacted]	○	○	○	○	○
c. Ease of movement	[redacted]	○	○	○	○	○
d. Rolling	○	○	○	○	○	○
e. Jumping	○	○	○	○	○	○

f. Landing	○	○	○	○	○	○
g. Running	○	○	○	○	○	○
h. Assuming a firing position	○	○	○	○	○	○
i. Bending	○	○	○	○	○	○

8. With Personal Protective Equipment	Not Applicable	Extreme Negative Impact 1	Very Negative Impact 2	Moderate Negative Impact 3	Slight Negative Impact 4	No Negative Impact 5
a. Overall impact on performance		○	○	○	○	○
b. Ease of motion		○	○	○	○	○
c. Ease of movement		○	○	○	○	○
d. Rolling	○	○	○	○	○	○
e. Jumping	○	○	○	○	○	○
f. Landing	○	○	○	○	○	○
g. Running	○	○	○	○	○	○
h. Assuming a firing position	○	○	○	○	○	○
i. Bending	○	○	○	○	○	○

9. With Body Armor	Not Applicable	Extreme Negative Impact 1	Very Negative Impact 2	Moderate Negative Impact 3	Slight Negative Impact 4	No Negative Impact 5
a. Overall impact on performance		○	○	○	○	○
b. Ease of motion		○	○	○	○	○
c. Ease of movement		○	○	○	○	○
d. Rolling	○	○	○	○	○	○
e. Jumping	○	○	○	○	○	○
f. Landing	○	○	○	○	○	○
g. Running	○	○	○	○	○	○
h. Assuming a firing position	○	○	○	○	○	○
i. Bending	○	○	○	○	○	○

10. Other Activities _____ (Please Specify)	Not Applicable	Extreme Negative Impact 1	Very Negative Impact 2	Moderate Negative Impact 3	Slight Negative Impact 4	No Negative Impact 5
a. Overall impact on performance		○	○	○	○	○
b. Ease of motion		○	○	○	○	○
c. Ease of movement		○	○	○	○	○
d. Rolling	○	○	○	○	○	○
e. Jumping	○	○	○	○	○	○
f. Landing	○	○	○	○	○	○

g. Running	○	○	○	○	○	○
h. Assuming a firing position	○	○	○	○	○	○
i. Bending	○	○	○	○	○	○

11. Please rate the impact of wearing the system on your body.

Extreme Negative Impact	Very Negative Impact	Moderate Negative Impact	Slight Negative Impact	No Negative Impact
1	2	3	4	5
○	○	○	○	○

12. During your training did the system cause any skin irritation, or other discomfort?

○ No

○ Yes ⟶ If Yes: 11a. What was/were the problem/s?

_____

_____

_____

_____

_____

13. For each of the system components listed below, please rate if there was any negative impact. (*Match the question letter to the belt area on the on the diagram above*).

	Extreme Negative Impact 1	Very Negative Impact 2	Moderate Negative Impact 3	Slight Negative Impact 4	No Negative Impact 5
a. Overall	○	○	○	○	○
b. Electrodes	○	○	○	○	○
c. Area Under Electronics Module	○	○	○	○	○
d. Belt Material	○	○	○	○	○
e. Adjustment Hooks	○	○	○	○	○
f. Shoulder Adjustment Fastener	○	○	○	○	○

For questions 14 to 19, rate each of the following statements. Place a circle around the number on the scale that best represents your feelings. For example, if you feel bad or have negative feelings you would circle a negative number that best represents the intensity of your negative feelings, if you feel good or have positive feelings you would circle a positive number that best represents the intensity of your positive feelings.

14. Rate how you feel you look when wearing this device. If you feel tense or on edge regarding how you look wearing the device that would indicate you are worried about your appearance, if you feel good or at ease about how you look wearing the device that would indicate you are confident about your appearance.

Worried Neutral Feelings Confident

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

15. I can feel the device on my body. I can feel the device moving or is it a wear and forget device.

Feel the Device Neutral Feeling Device is Wear & Forget

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

16. The device can cause some harm or is beneficial. The device is painful or comfortable to wear.

Causes Harm Neutral Feelings Is Beneficial

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

17. Wearing the device makes me feel physically different or feel the same. I feel strange wearing the device or I feel like it is just another piece of equipment worn.

Feel Strange Neutral Feelings Feel the Same

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

18. The device affects or does not affect the way I move. The device inhibits/restricts my movement or I have complete freedom of movement.

Restricts Movement Neutral Feelings Freedom of Movement

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

19. I do not feel secure or I feel secure wearing the device.

Feel Insecure Neutral Feelings Feel Secure

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

20. Did the system come apart or break?

- ○ No
- ○ Yes ⟶ If Yes: 20a. Please explain how the system broke or came apart, and how you fixed the problem.

_____

21. Is the system acceptable to wear for an extended period of eight hours or more?

- ○ Yes
- ○ No ⟶ If No: 21a. Please explain why the system is not

_____

22. If this system were able to provide you with better medical care would you wear this system during a Chemical, Biological, Radiological, Nuclear, or Explosive (CBRNE) incident?

- ○ Yes
- ○ No ⟶ If No: 22a. Please explain why you would not wear the system:

_____

23. Have you previously worn any type of heart rate monitor, such as the Polar Heart Rate Monitor or other Sports Monitors?

- ○ Yes
- ○ No

24. Would you like your heart rate and other vital signs displayed?

○ Yes ⟶ If Yes **24a.** Please explain where (on wrist watch?) _____

○ No

25. Would you recommend this system as a medical monitoring system to other CBRNE personnel?

○ Yes

○ No ⟶ If No: **25a.** Please explain why you would not recommend

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26. Any other comments please feel free to write them below or on the back of this survey.